IX. ATMOSPHERIC DEPOSITION IN THE TERRITORY OF THE CR

Atmospheric deposition refers to the flux of substances from the atmosphere to the surface of the Earth (Braniš, Hůnová 2009). This is an important process contributing to self-purification of the air; but it is also responsible for the input of pollutants into other components of the environment. Atmospheric deposition has both wet and dry components. The wet component is connected with the occurrence of atmospheric precipitation (vertical deposition: rain, snow, hail, and horizontal deposition: fog, rime, icing) and is thus episodic in character. The dry component corresponds to the deposition of gases and particles by various mechanisms and occurs continuously.

The atmospheric deposition of most monitored substances in Europe has decreased substantially over the past twenty years, but still remains a problem in a number of regions (EEA 2011). In the CR, the chemical composition of atmospheric precipitation and atmospheric deposition has been monitored for a long time at a relatively large number of localities.

In 2020, data on the chemical composition of atmospheric precipitation were provided to the Air Quality Information System (AQIS) from 39 locations in the CR. Measurements in the CR are provided by CHMI (14 localities), CGS (10 localities), VÚLHM (10 localities), HBÚ AV ČR (2 localities), and ÚH AV ČR, ÚVGZ AV ČR and GLÚ AV ČR (1 locality each). Furthermore, data from 6 Polish localities (GIOS) were provided from border areas (Fig. IX.1, Tab. IX.4).

The substances presented in the chapter on atmospheric deposition have no limit values set by legislation, as is the case for ambient air pollutants. Therefore, another colour scale has been

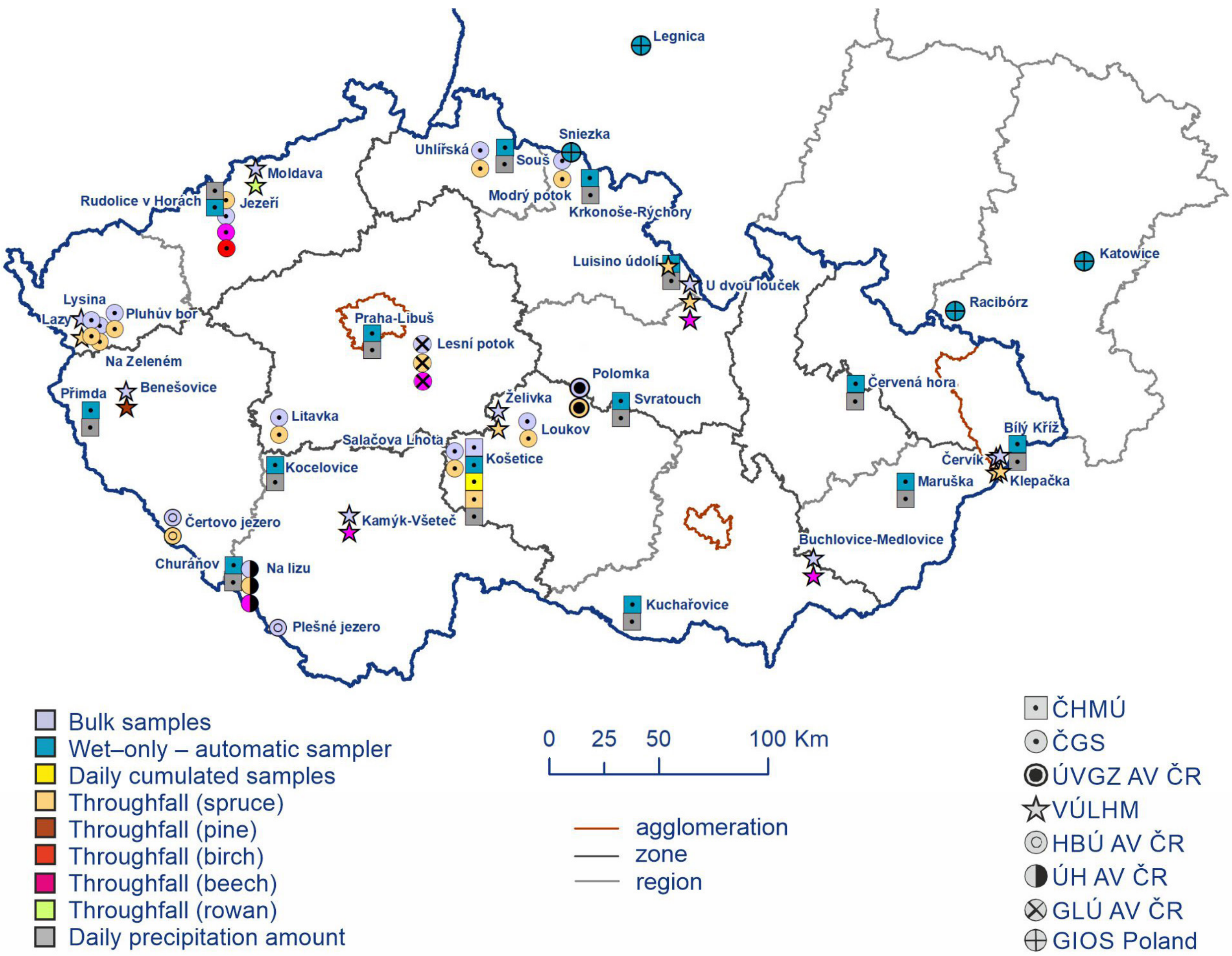

Fig. IX.1 Station networks monitoring atmospheric precipitation quality and atmospheric deposition, 2020

chosen to improve the clarity of deposition maps. More detailed information on atmospheric deposition, sampling, measurement and quantification of its components and specifications for preparation of maps are available at CHMI (2021d).

Results

The year 2020 was above-normal in terms of precipitation. The average annual precipitation of 766 mm represents 112% of the long-term 1981–2010 normal (for more see Chapter III). Higher precipitation totals compared to 2019 (634 mm) resulted in an increase in the wet deposition of oxidised forms of nitrogen (N_NO_3^-), the total wet deposition of nitrogen, and the total deposition of nitrogen.

Deposition of sulphur

The average sulphur deposition flux in 2020 was 0.388 g.m^{-2}.year^{-1} (Table IX.1). Compared to 2019 (0.419 g.m^{-2}.year^{-1}), this is a decrease of 8%.

The field of total sulphur deposition represents the total level of sulphur deposition on the area of the CR. Its quantification is based on SO_4^{2-} concentrations measured in atmospheric precipitation and SO_2 air pollution concentrations. This value was 30 577 t in 2020 (Table IX.2), compared to 33 032 t in 2019. Total sulphur deposition is highest in the Krušné hory and Ostrava areas (Fig. IX.4).

Wet deposition of sulphur (S_SO_4^{2-}) reached the value of 13 793 t in 2020, compared to 13 657 t in 2019. The highest values of the wet component occurred in mountain areas, namely in the Moravian-Silesian Beskydy, Jeseníky, Krkonoše, Bohemian-Moravian Highlands, and Šumava (Fig. IX.2). In 2020, the dry deposition of sulphur (S_SO_2) amounted to 16 784 t, compared to 19 365 t. in 2019 The highest values of the dry component occurred in the Krušné hory and the Moravian-Silesian Beskydy areas (Fig. IX.3).

In 2020, throughfall deposition of sulphur (S_SO_4^{2-}) in forested areas of the CR reached 7 492 t, with maximum values occurring in mountain areas (Fig. IX.5). A map showing throughfall sulphur deposition was prepared for forested areas on the basis of fields of sulphur concentrations in throughfall precipitation and from verified fields of precipitation, modified by the percentage amount of precipitation measured under vegetation at individual stations, which ranged from 49% (Luisino údolí) to 90% (U dvou louček) of the total precipitation in open areas in 2020. Throughfall deposition generally includes wet vertical and horizontal deposition (from fogs, low clouds and rime) and the dry deposition of particles and gases in forests.

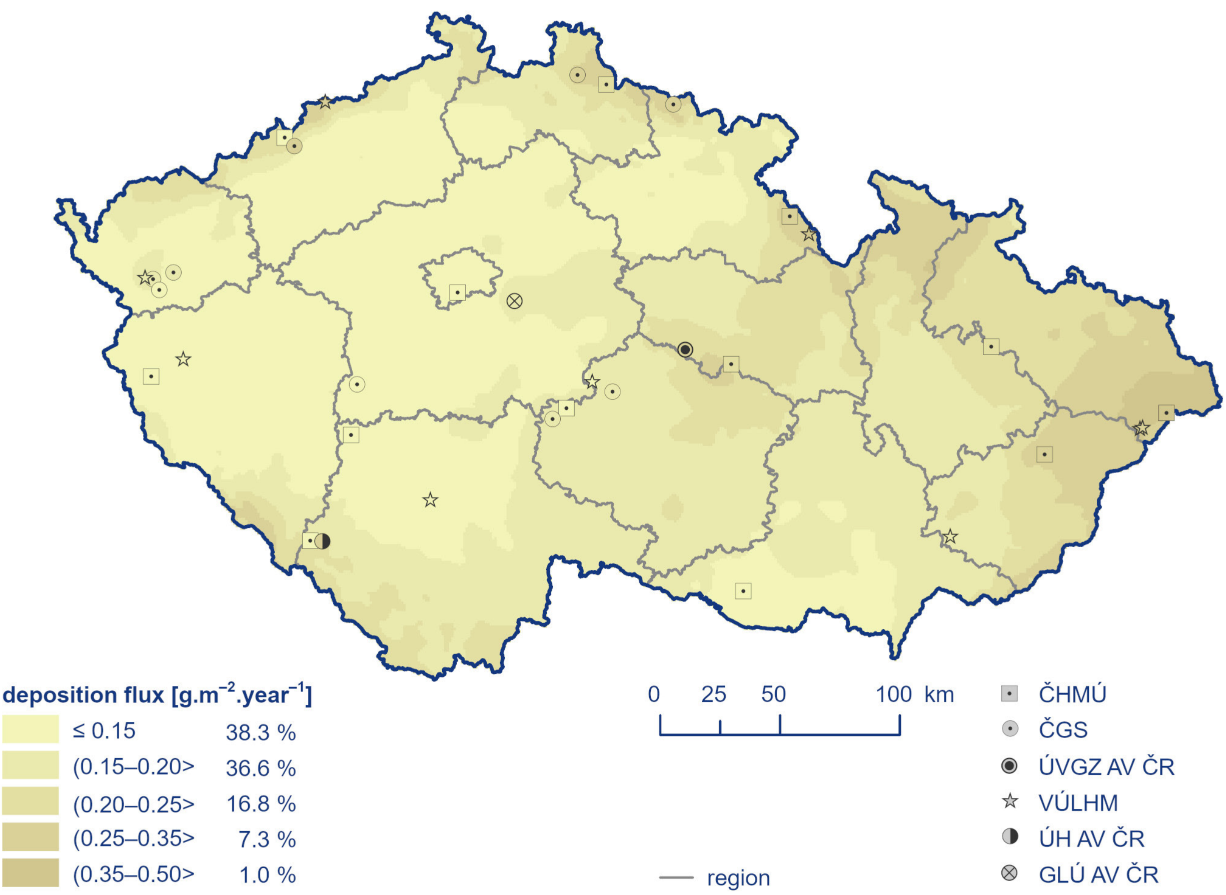

Fig. IX.2 Field of annual wet deposition of sulphur (S_SO_4^{2-}), 2020

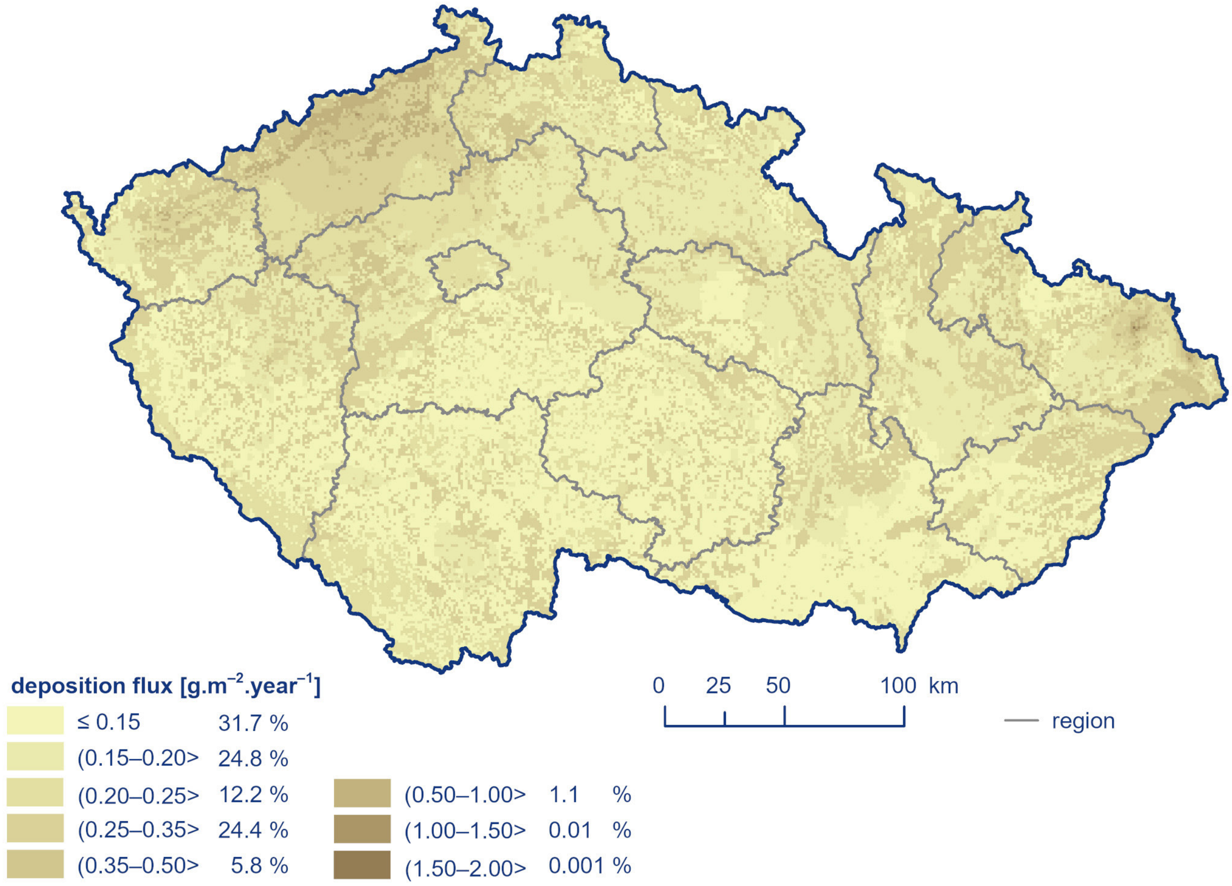

Fig. IX.3 Field of annual dry deposition of sulphur (S_SO_2), 2020

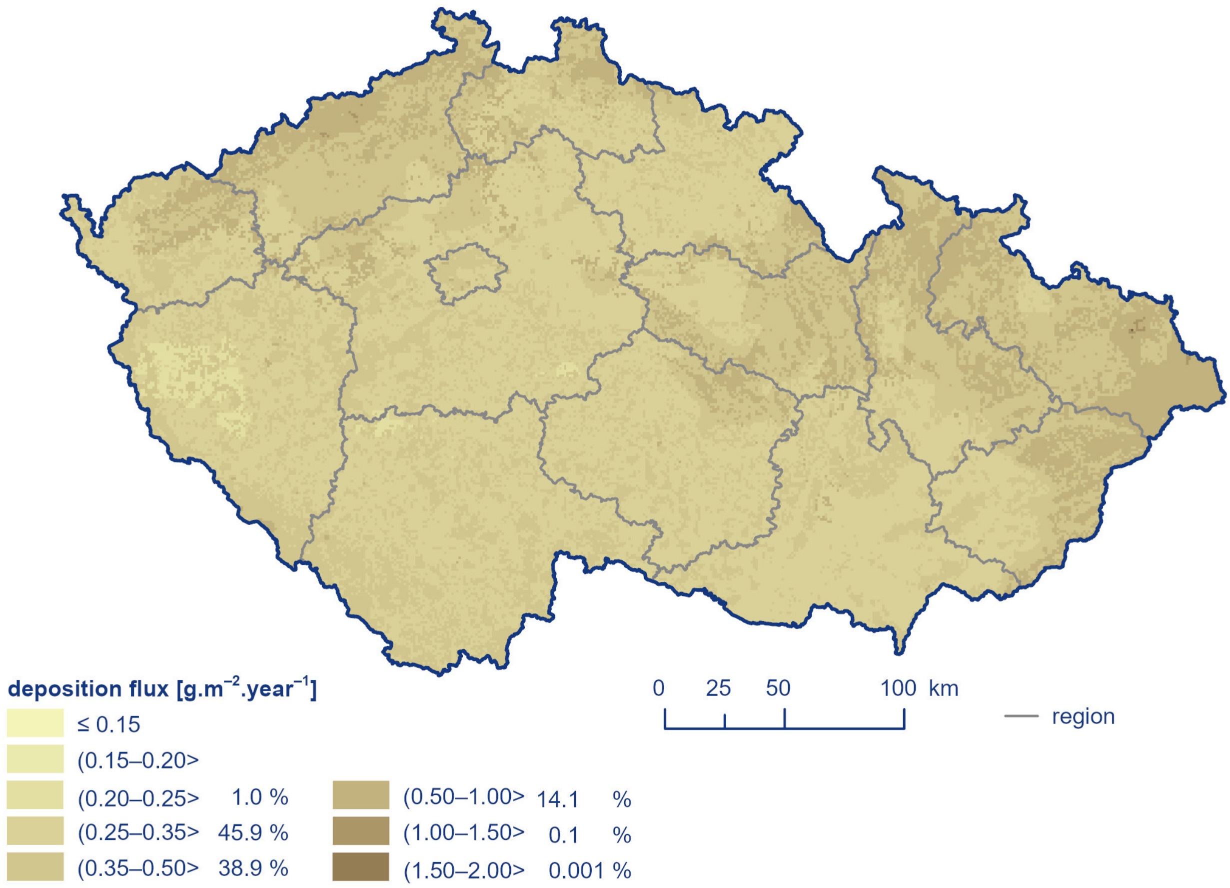

Fig. IX.4 Field of annual total deposition of sulphur, 2020

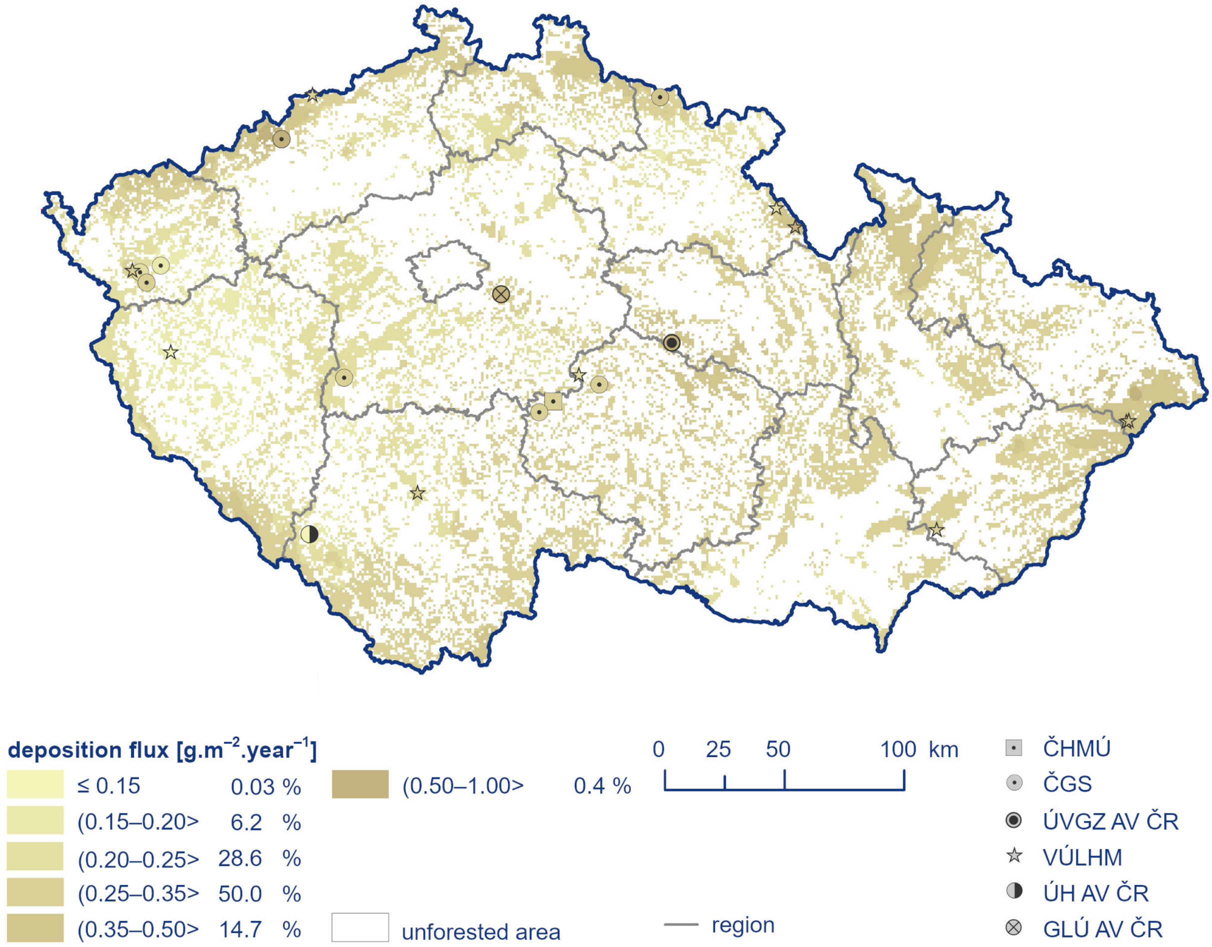

Fig. IX.5 Field of annual throughfall deposition of sulphur, 2020

Table IX.1 Average deposition fluxes of S, N and H in the Czech Republic, 2020

Element	Deposition	g.m^{-2}.year^{-1}	keq.ha^{-1}.year^{-1}
S (SO_4^{2-})	wet	0.175	0.109
S (SO_2)	dry	0.213	0.133
S	total	0.388	0.242
N (NO_3^-)	wet	0.182	0.130
N (NH_4^+)	wet	0.363	0.259
N (NO_x)	dry	0.170	0.121
N	total	0.715	0.511
H (pH)	wet	0.003	0.027
H (SO_2. NO_x)	dry	0.025	0.252
H	total	0.028	0.280

Table IX.2 Estimate of the total annual deposition in the Czech Republic (78 841 sq. km) in tonnes, 2020

	Deposition [t]		
	wet	**dry**	**total**
S	13 793	16 784	30 577
N (ox)	14 382	13 397	27 779
N (red)	28 617		
N (ox + red)	42 999		56 396
H+	218	2 006	2 224
Pb	31	17	
Cd	2.0	0.9	

Table IX.3 Estimate of the total annual deposition of sulphur on the forested part of the Czech Republic (26 428 sq. km) in tonnes, 2001–2020

	Deposition [t]	
	total	throughfall
2001	27 894	36 899
2002	25 984	31 011
2003	21 306	26 818
2004	23 247	32 835
2005	22 855	26 461
2006	21 975	25 660
2007	17 445	29 279
2008	15 528	30 197
2009	16 590	26 193
2010	17 621	27 944
2011	15 118	18 691
2012	15 311	19 079
2013	16 530	19 723
2014	16 810	12 836
2015	13 294	16 044
2016	12 625	19 724
2017	14 621	12 608
2018	14 870	14 002
2019	13 133	10 707
2020	13 057	7 492

Deposition of nitrogen

The average nitrogen deposition flux in 2020 was 0.715 $g.m^{-2}.year^{-1}$ (Table IX.1). Compared to 2019 (0.694 $g.m^{-2}.year^{-1}$), this is an increase of 3%.

The total nitrogen deposition on the area of the CR in 2020 amounted to 56 396 t (Tab. IX.2). In contrast to sulphur deposition, this was an increase compared to 2019, when the value was 54 749 t. The highest values of total nitrogen deposition occurred in the Jeseníky, Moravian-Silesian Beskydy, Orlické hory, Šumava and Novohradské hory mountain regions (Fig. IX.10).

On the contrary, some partial components of nitrogen deposition reached lower values. The wet deposition of oxidized forms of nitrogen ($N\_NO_3^-$) was 14 382 t in 2020 (Fig. IX.6), compared to 15 815 t in 2019. The wet deposition of reduced forms ($N\_NH_4^+$) increased in 2020 to a value of 28 617 t (Fig. IX.7), compared to 24 437 t in 2019. The total wet deposition of nitrogen (sum of the wet deposition of $N\_NO_3^-$ and $N\_NH_4^+$) in 2020 was equal to 42 999 t, while in 2019 was only 40 252 t. The highest values of total wet nitrogen deposition were recorded in the Šumava, Krkonoše, Jizerské hory, Orlické hory, Bohemian-Moravian Highlands, Jeseníky and Moravian-Silesian Beskydy mountain regions (Fig. IX.8).

The dry deposition of oxidized forms of nitrogen (N_NO_X) reached 13 397 t in 2020, compared to to 14 497 t in 2019. The highest values were reached in the territory of larger cities and along major roads (Fig. IX.9).

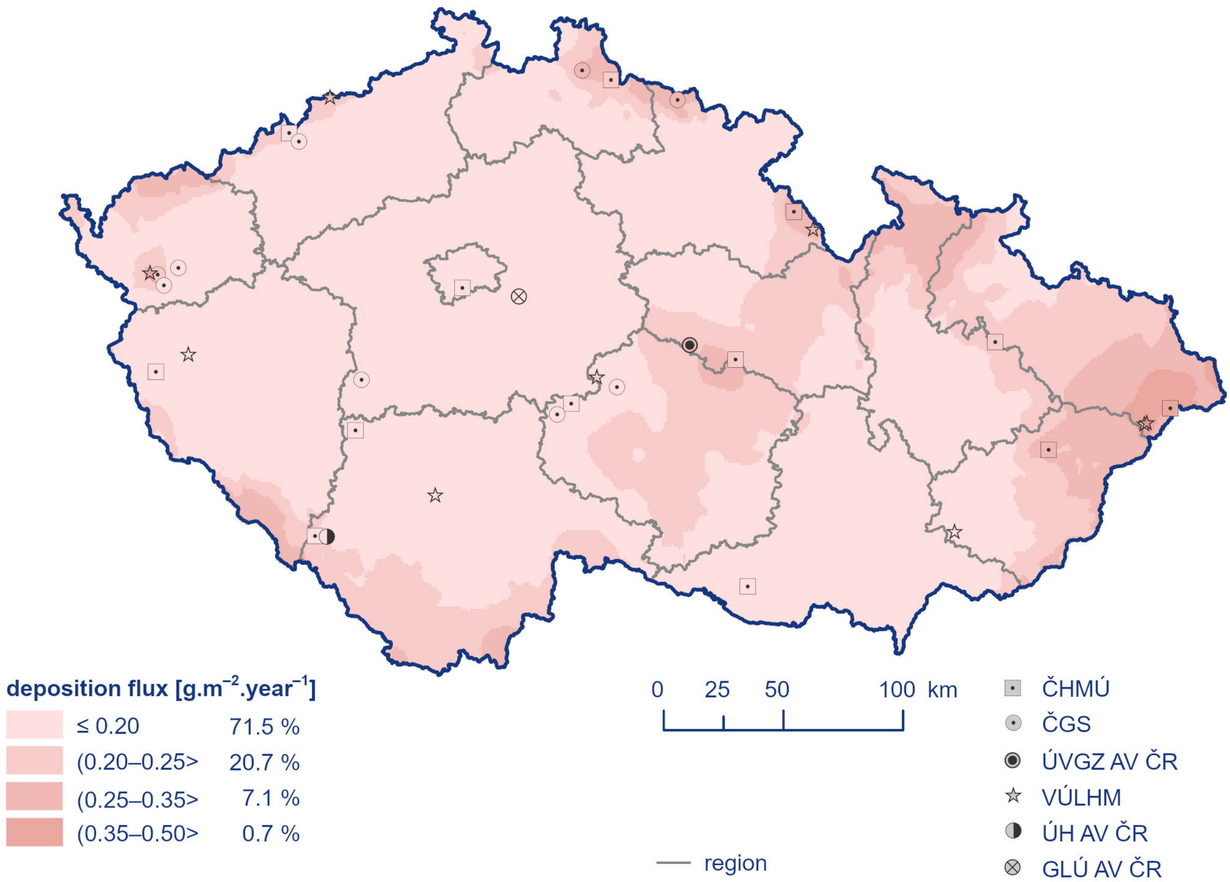

Fig. IX.6 Field of annual wet deposition of nitrogen ($N\_NO_3^-$), 2020

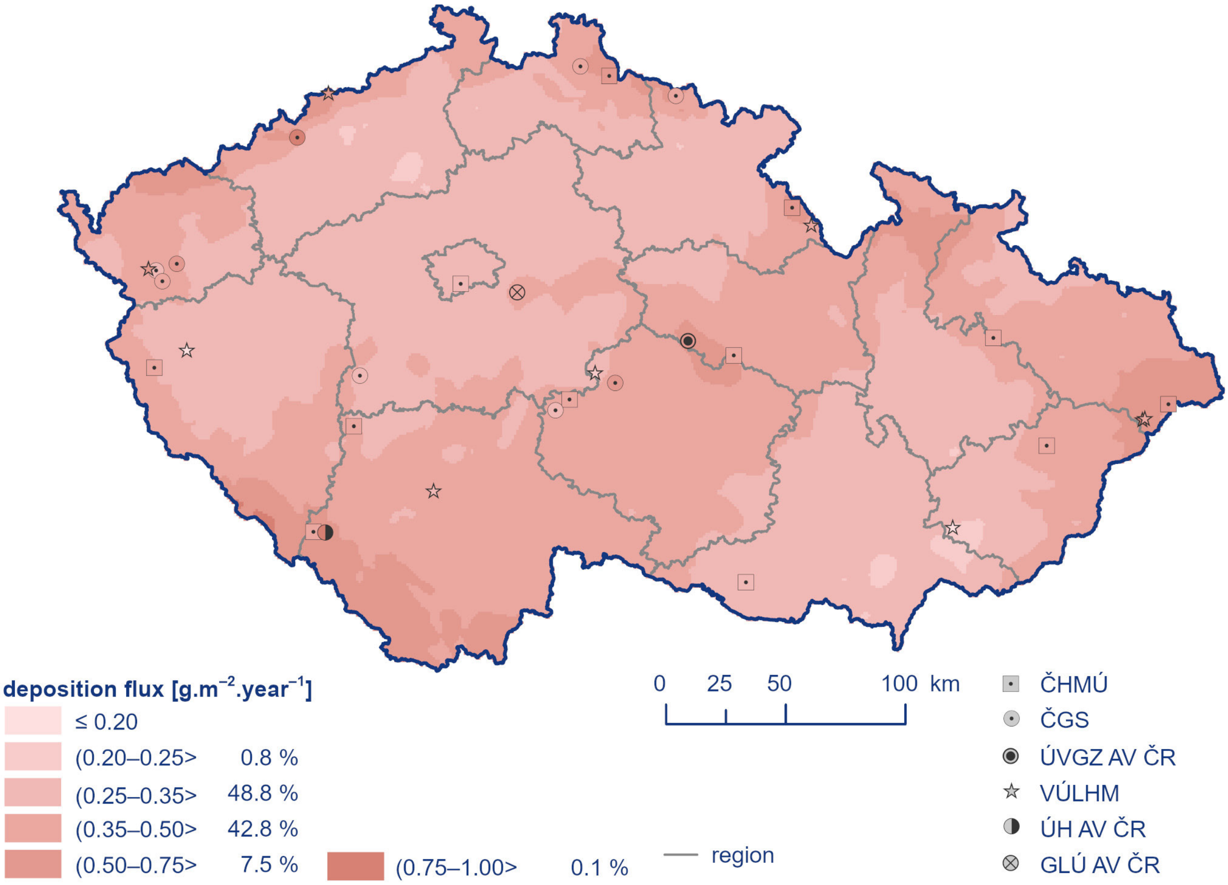

Fig. IX.7 Field of annual wet deposition of nitrogen (N_NH$_4^+$), 2020

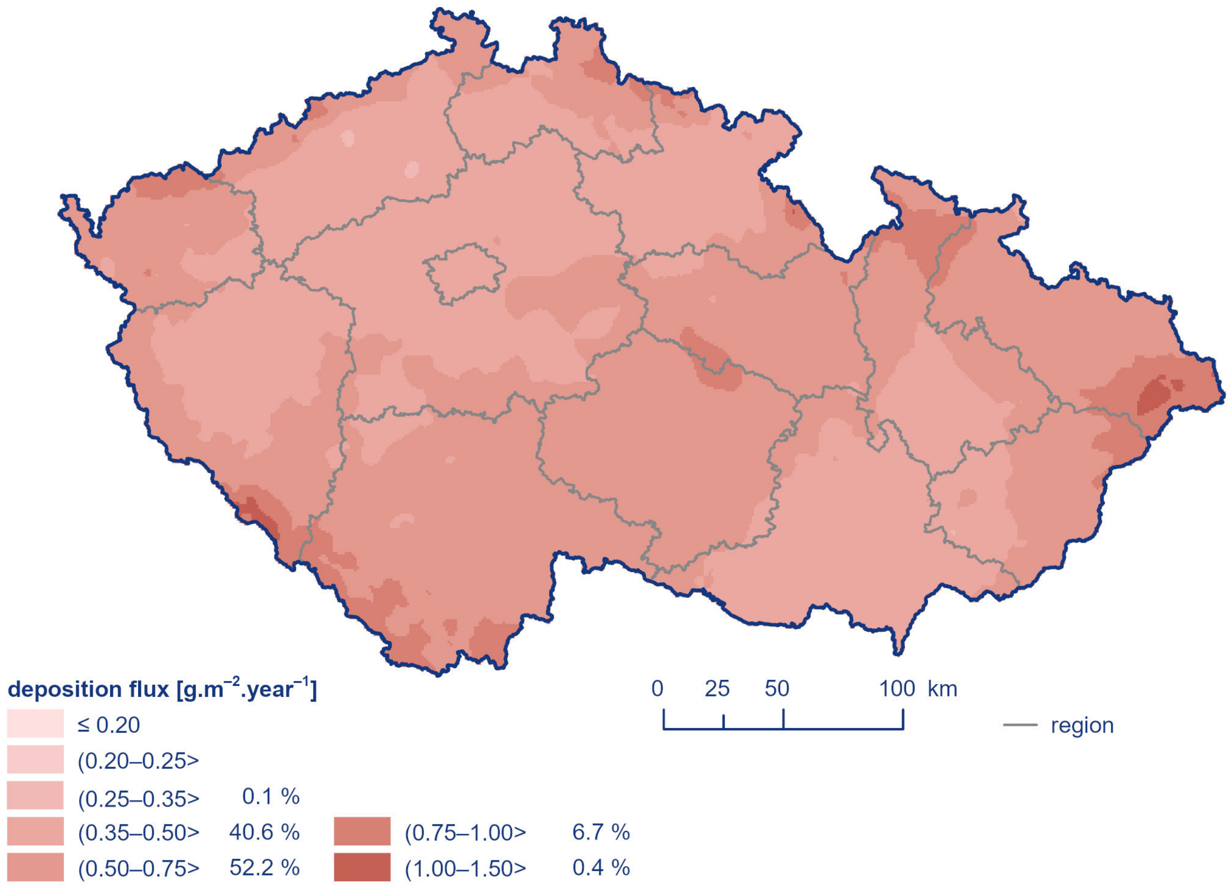

Fig. IX.8 Field of annual total wet deposition of nitrogen, 2020

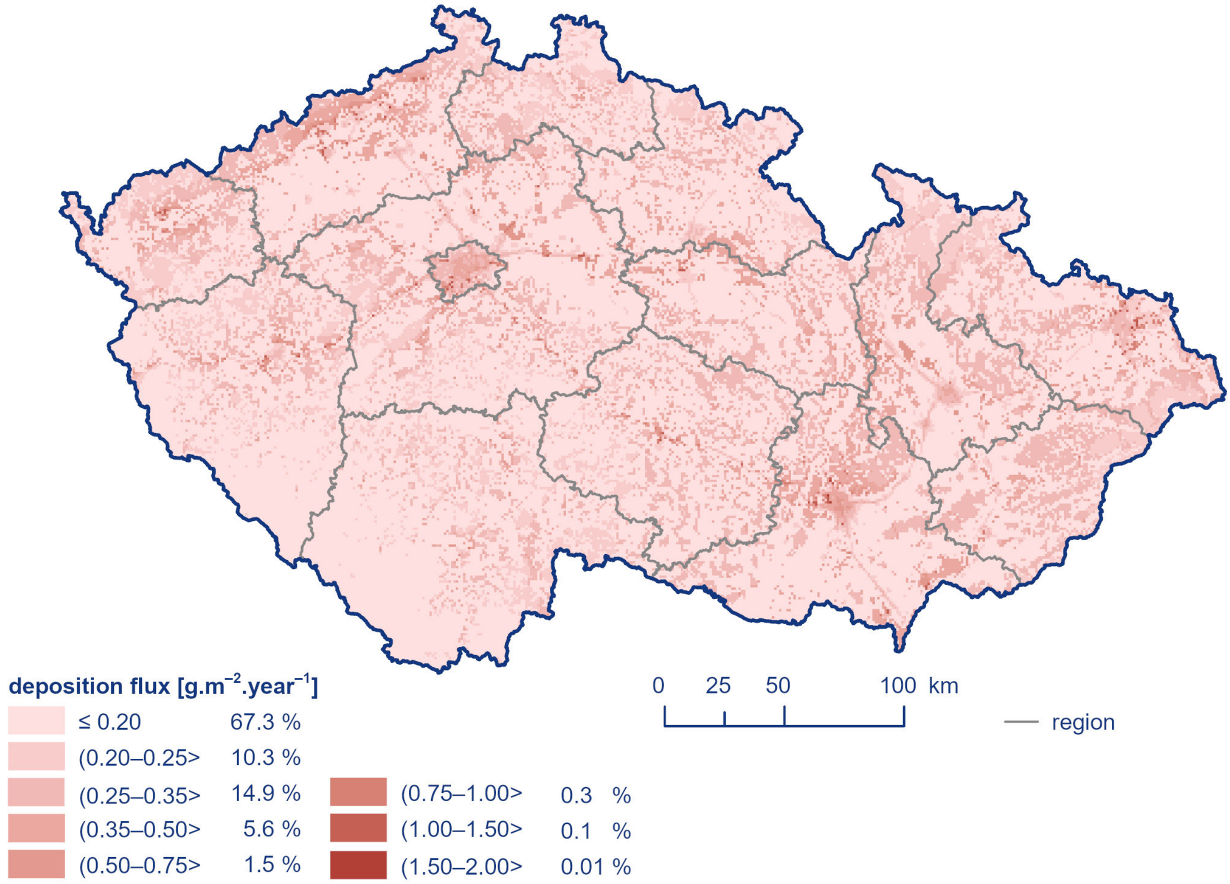

Fig. IX.9 Field of annual dry deposition of nitrogen (N_NO$_x$), 2020

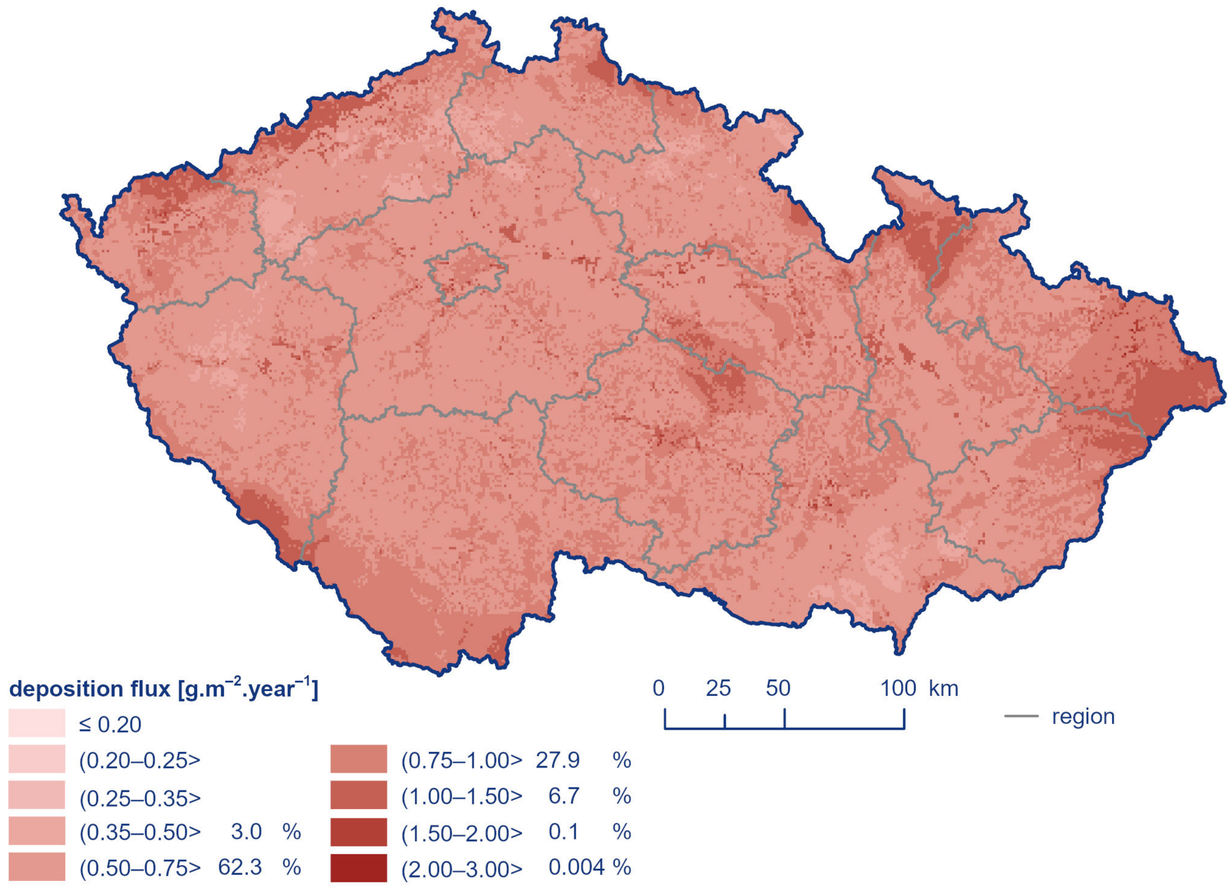

Fig. IX.10 Field of annual total deposition of nitrogen, 2020

Deposition of hydrogen, lead, cadmium, nickel and chloride ions

The average hydrogen deposition flux in 2020 was 0.028 g.m^{-2}.year^{-1} (Table IX.1). Compared to 2019 (0.032 g.m^{-2}.year^{-1}), this is a decrease of 14%.

The total deposition of hydrogen ions on the area of the CR in 2020 was 2 224 t (Table IX.2, Fig. IX.13). Compared to 2019 (2 535 t), this is a slight decrease. There was also a decrease in both partial components of hydrogen ion deposition. The wet component reached 218 t in 2020 (Fig. IX.11), compared to 2019, when the value was 290 t. The dry component in 2020 was equal to 2 006 t (Fig. IX.12), compared to 2019 with 2 245 t. The deposition of hydrogen ions was highest in the Šumava, Krušné hory, Jizerské hory, Orlické hory, Hrubý Jeseník and Moravian-Silesian Beskydy mountain regions.

Lead wet deposition in 2020 (31 t) was the same as in 2019 (31 t). The highest values occurred in the areas of the Jizerské hory, Orlické hory, Jeseníky and Moravian-Silesian Beskydy mountain regions (Fig. IX.15). The dry deposition was equivalent, reaching 17 t in 2020, compared to 18 t in 2019. The highest values were in the Ostrava, Moravian-Silesian Beskydy and Brdy regions (Fig. IX.16).

Wet deposition of cadmium reached 2.0 t in 2020, which is a year-on-year increase compared to 2019 (1.6 t). On the contrary, dry deposition was lower in 2020 (0.9 t) compared to 2019 (1.1 t). Over the long term, cadmium deposition is highest in the Jablonec nad Nisou district (Fig. IX.17, Fig. IX.18).

The annual wet deposition of nickel ions reaches the highest values in the Lesní potok, Červík, Loukov, Uhlířská, and Souš localities (Fig. IX.19). Similarly to other monitored pollutants, the wet deposition of chloride ions is highest in mountain areas of the CR (Fig. IX.14).

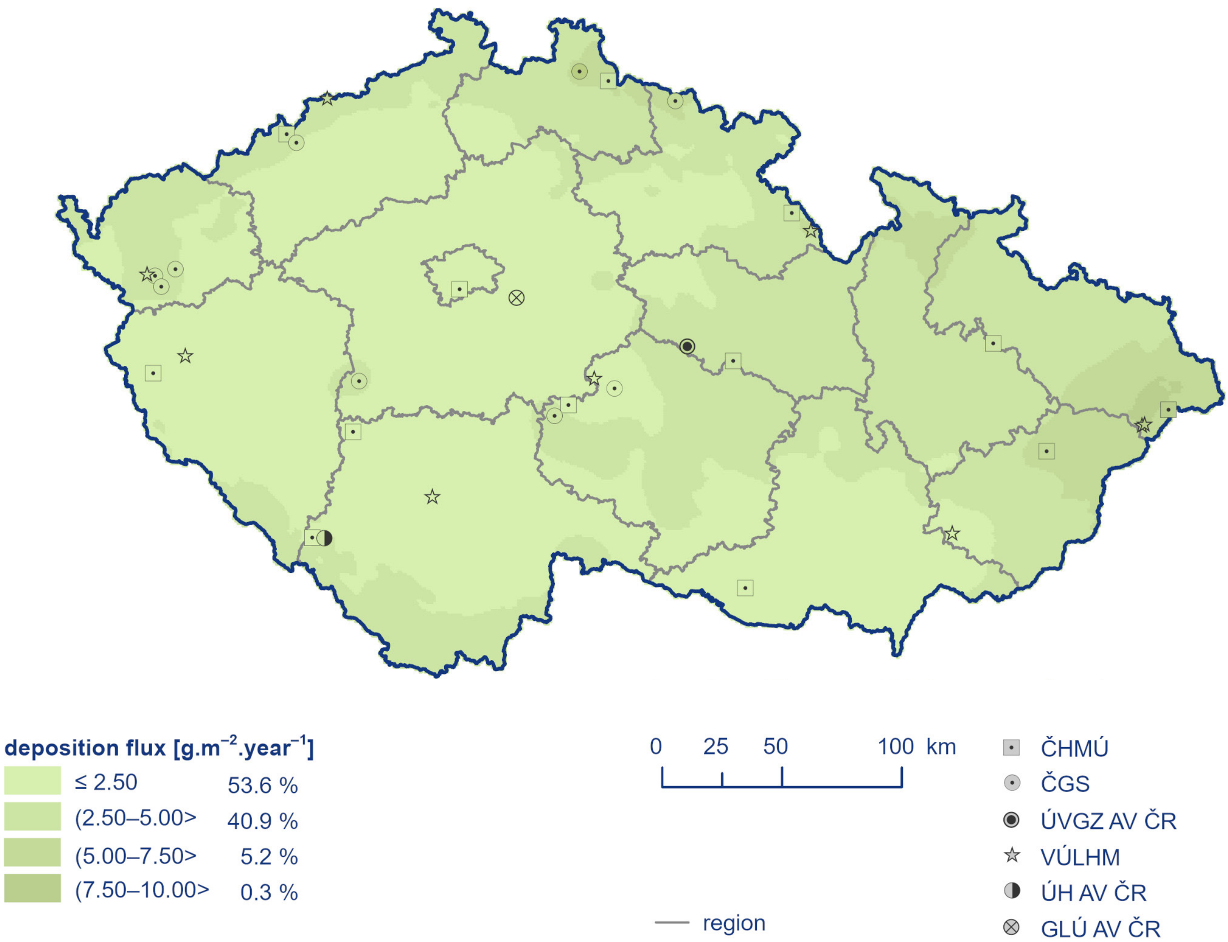

Fig. IX.11 Field of annual wet deposition of hydrogen ions, 2020

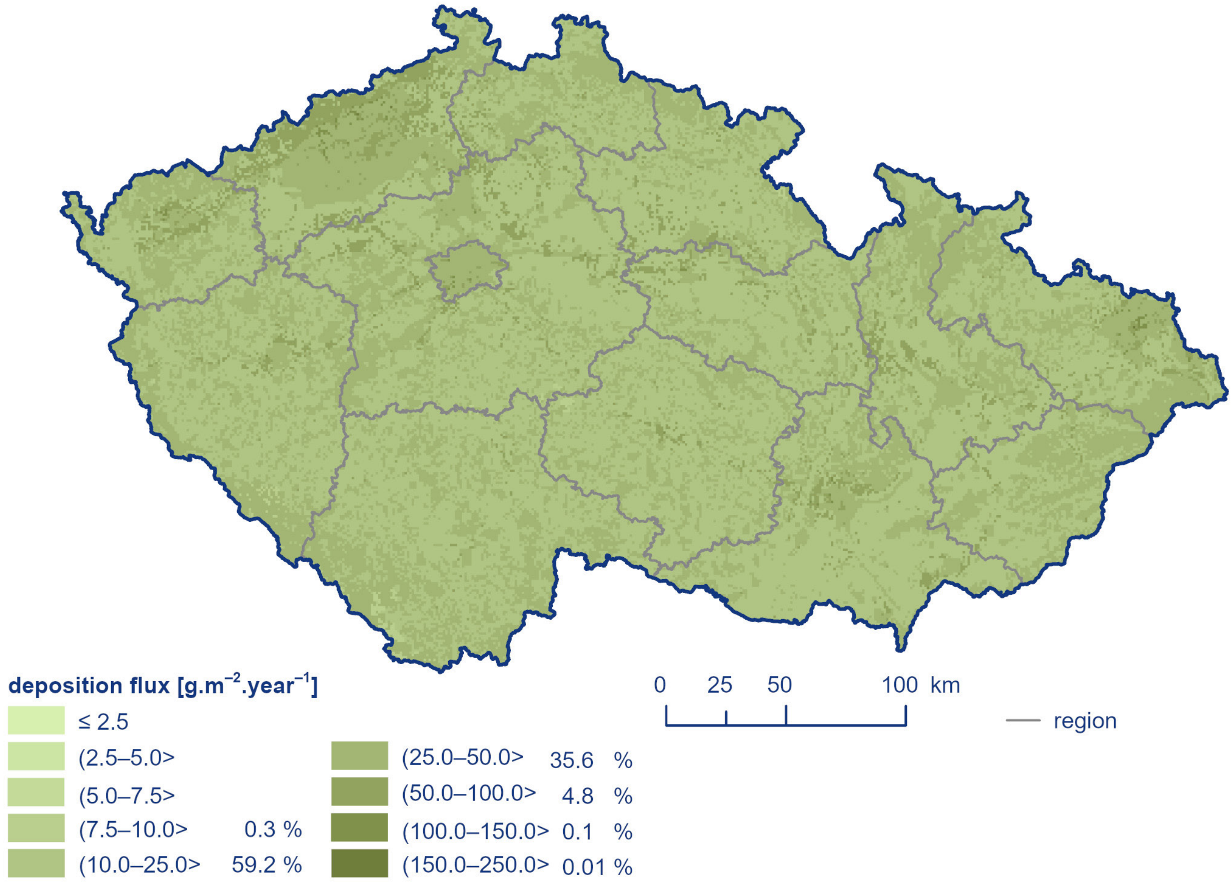

Fig. IX.12 Field of annual dry deposition of hydrogen ions corresponding to SO_2 and NO_x gas deposition, 2020

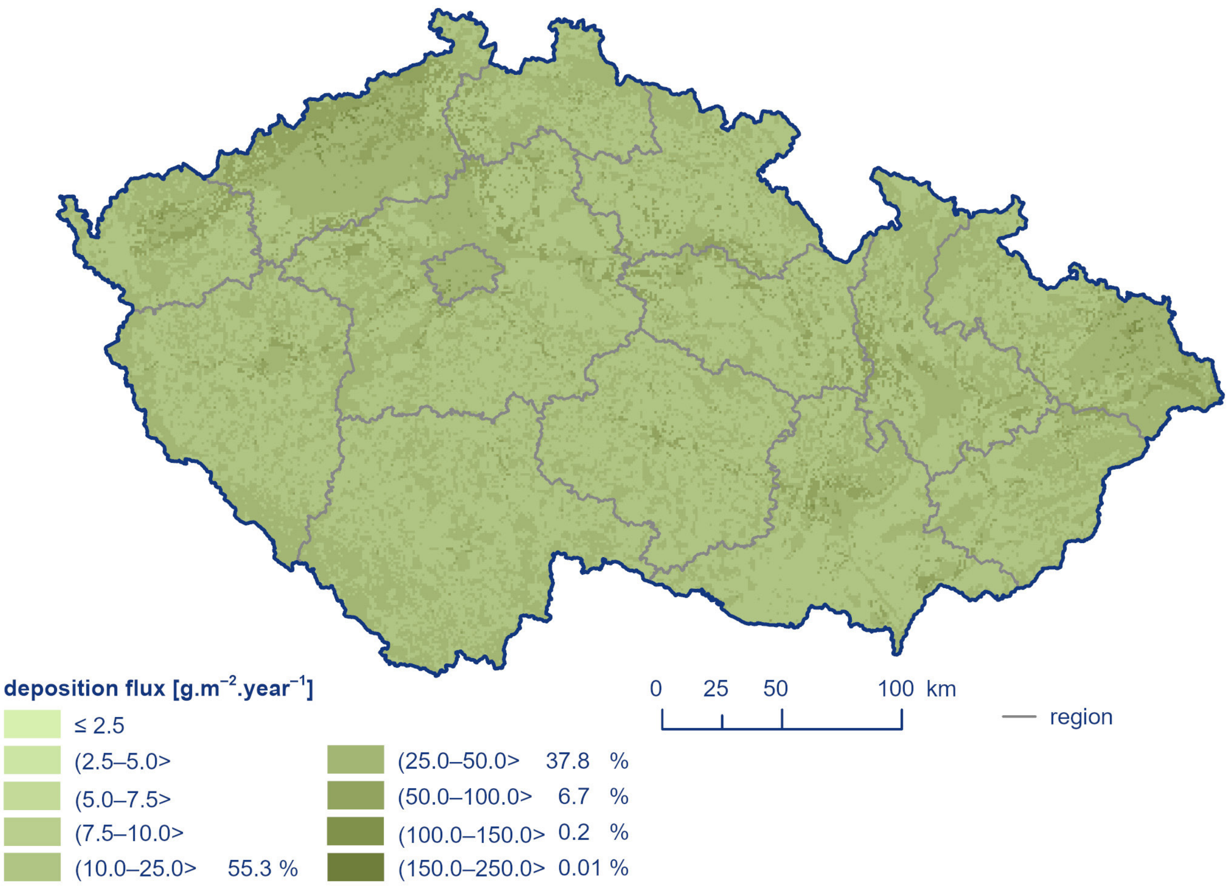

Fig. IX.13 Field of annual total deposition of hydrogen ions, 2020

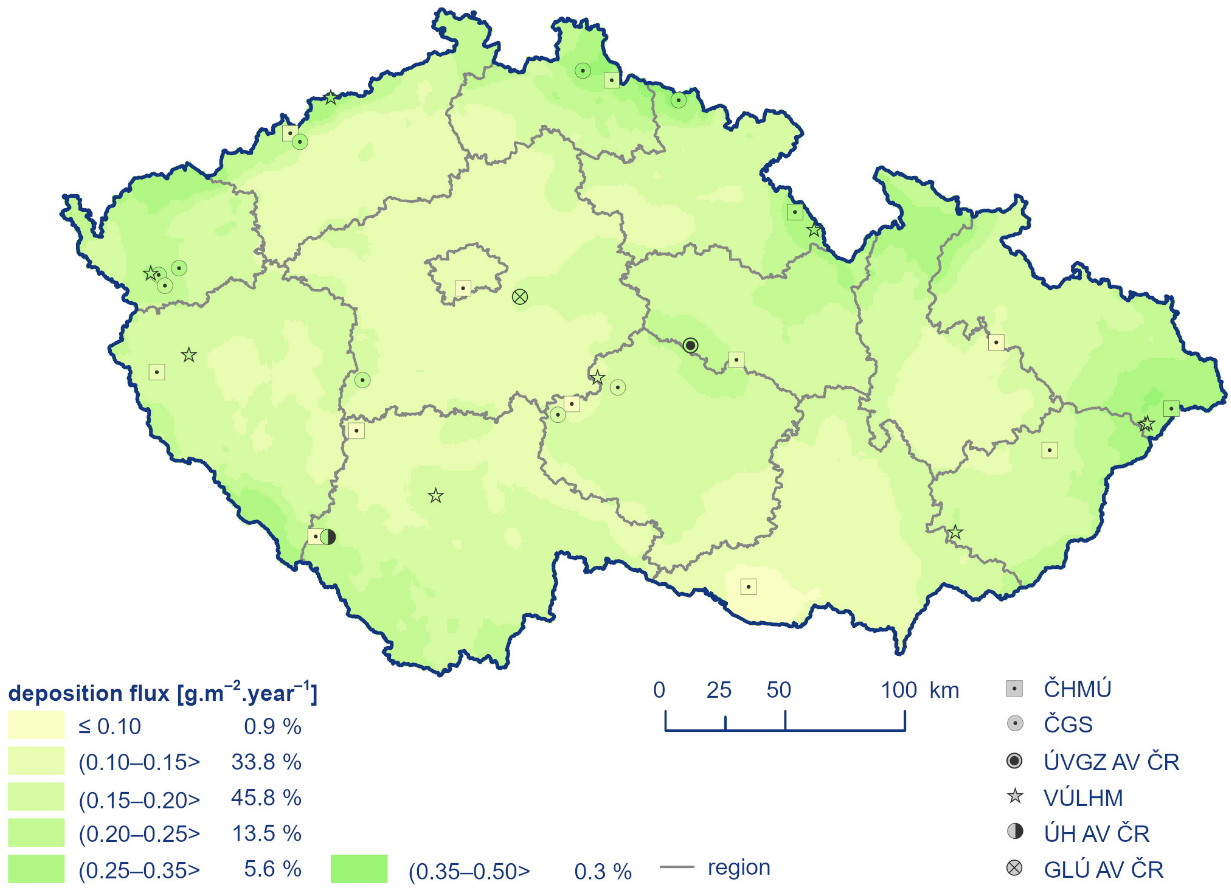

Fig. IX.14 Field of annual wet deposition of chloride ions, 2020

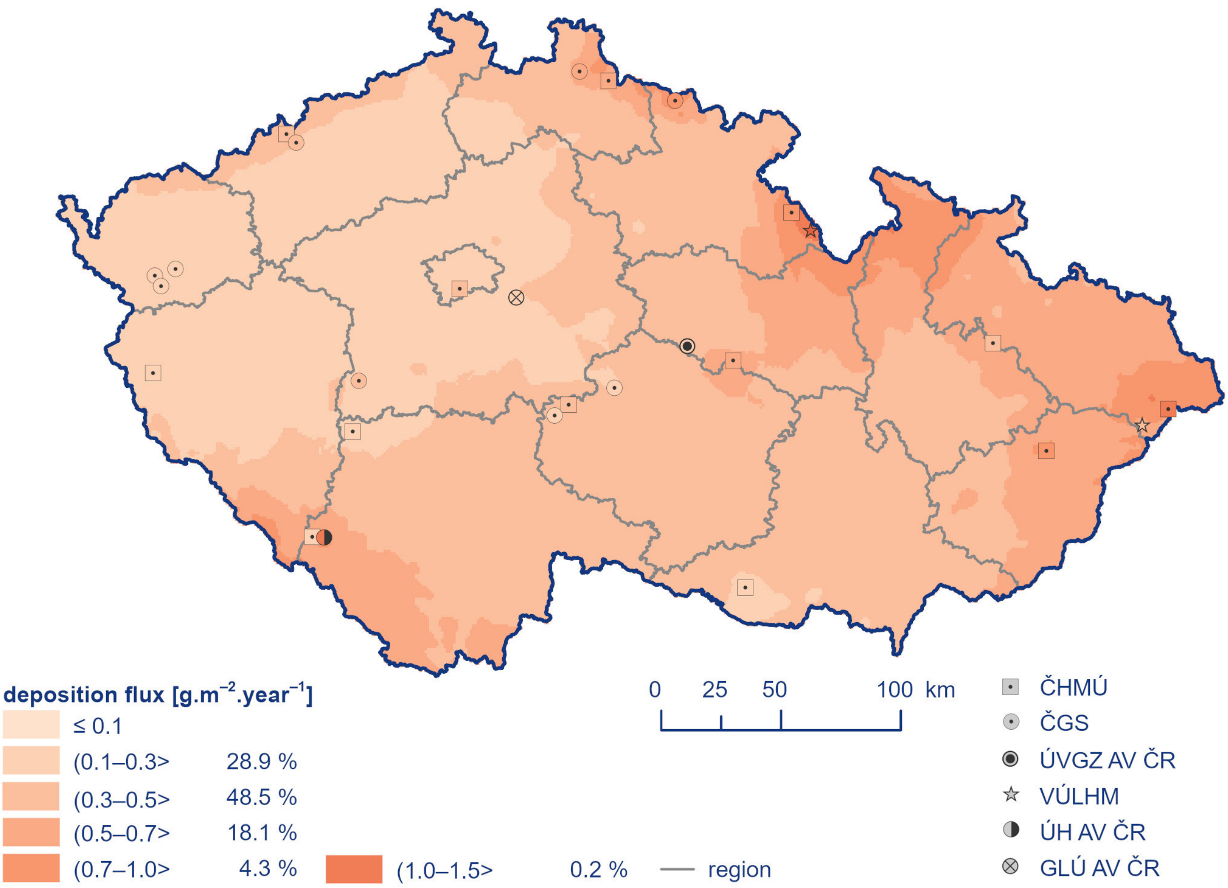

Fig. IX.15 Field of annual wet deposition of lead ions, 2020

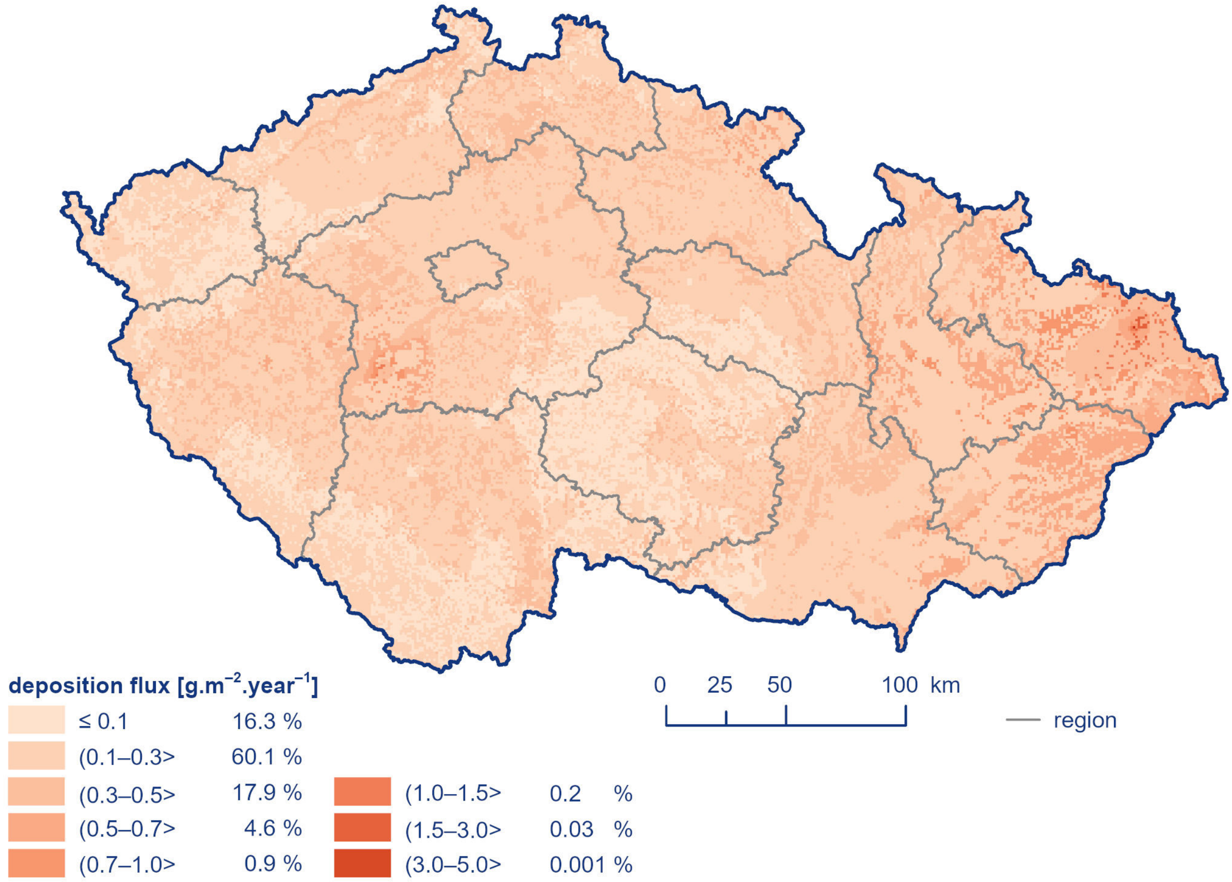

Fig. IX.16 Field of annual dry deposition of lead, 2020

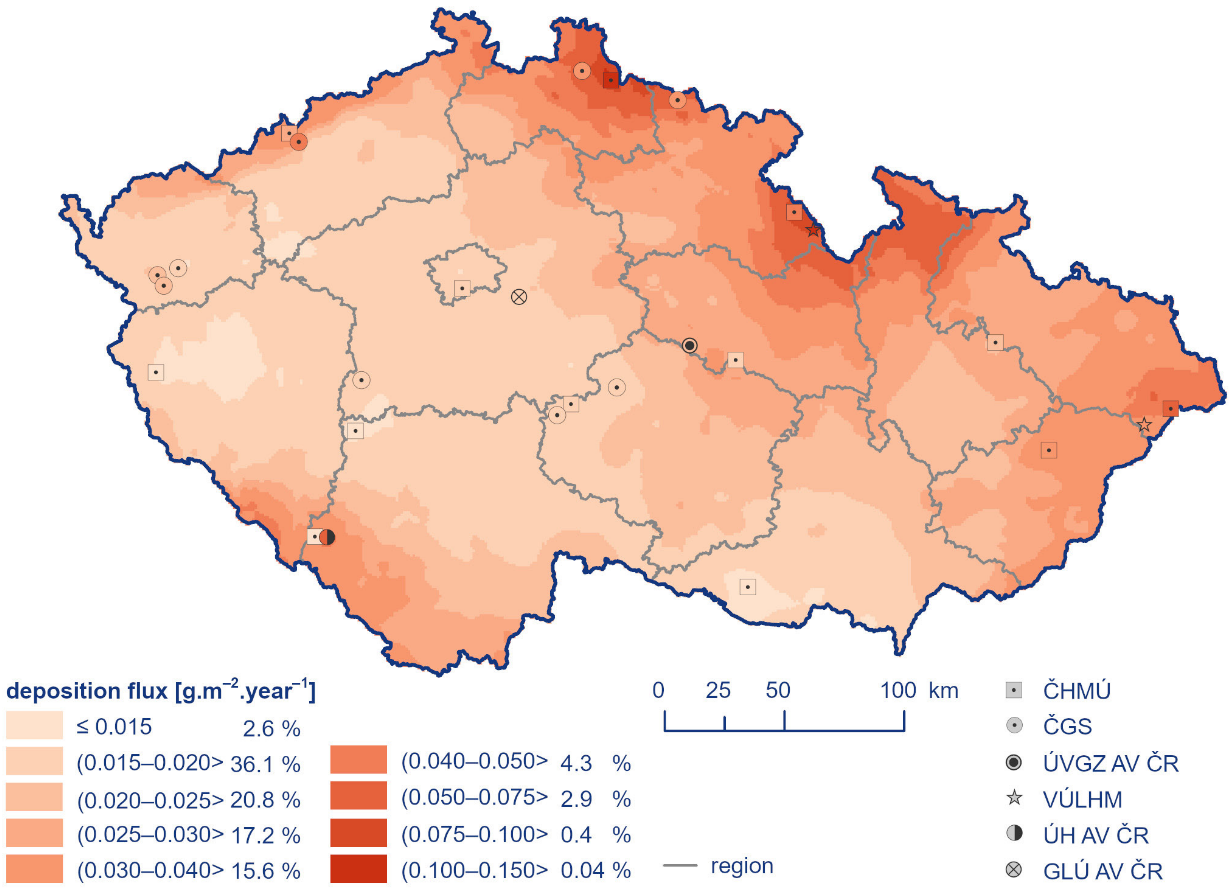

Fig. IX.17 Field of annual wet deposition of cadmium ions, 2020

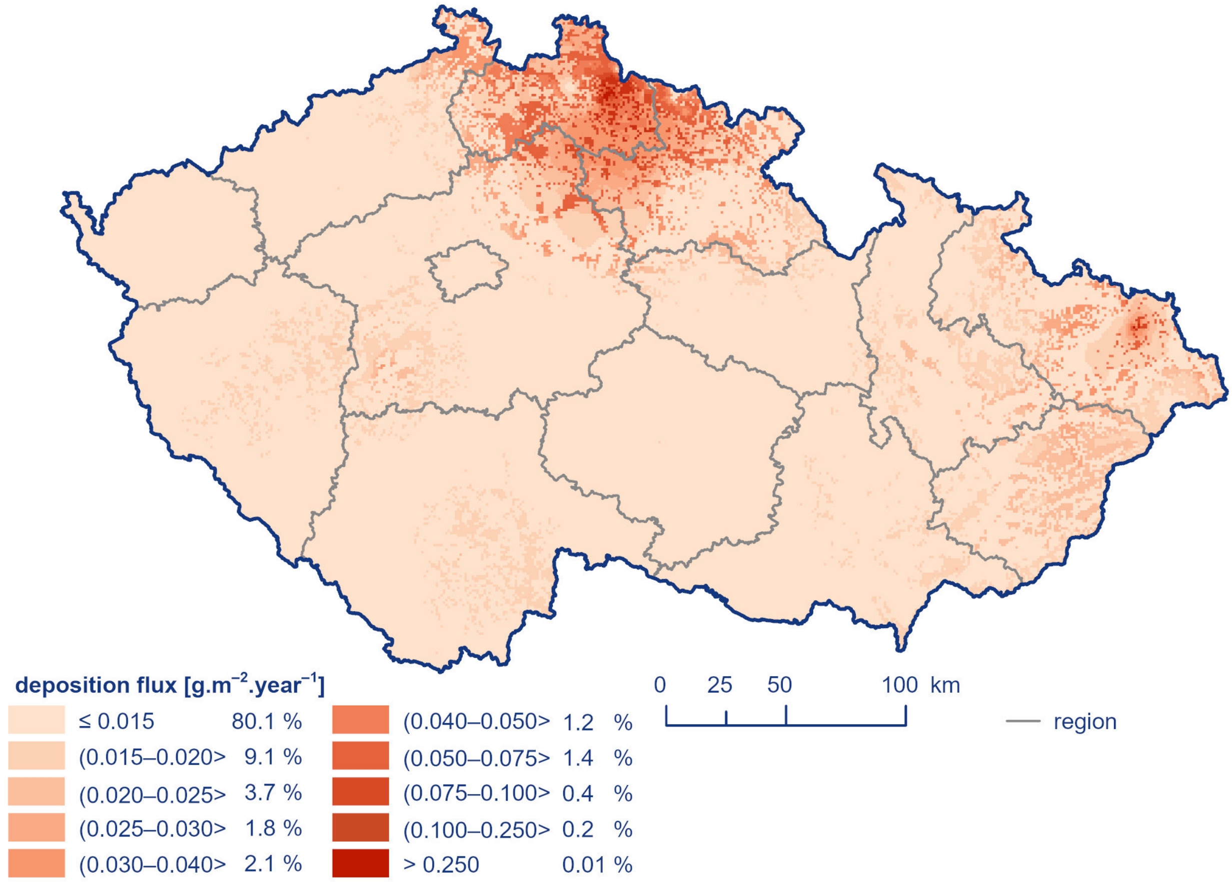

Fig. IX.18 Field of annual dry deposition of cadmium, 2020

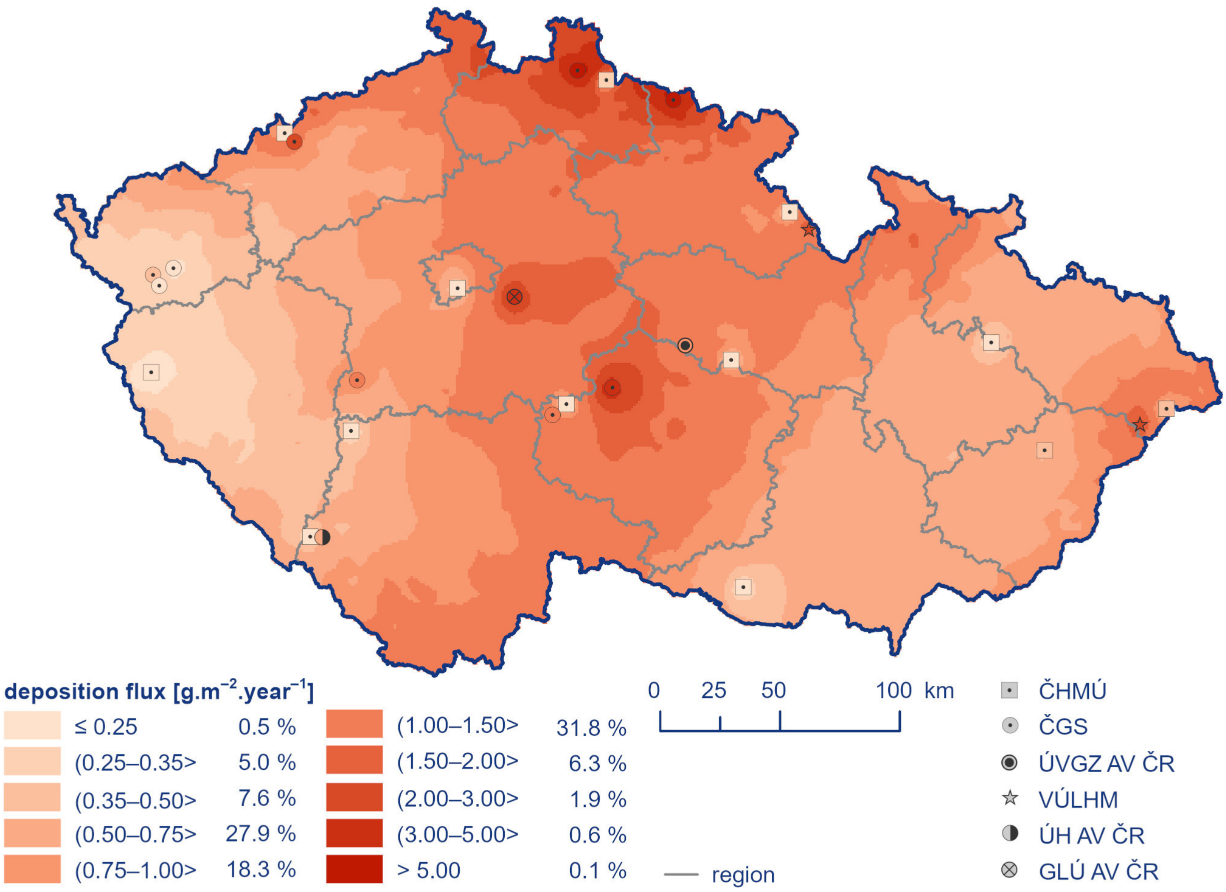

Fig. IX.19 Field of annual wet deposition of nickel ions, 2020

Trends in deposition

In the 1990s, values of total annual sulphur deposition were significantly higher than 100 000 t. Since 2000, a declining trend can be observed (Fig. IX.21). In 2000–2006, total deposition remained in the range of approx. 65 000–75 000 t, except for 2003, which was significantly subnormal in terms of precipitation (516 mm, i.e. 77% of the long-term normal). Since 2011, annual sulphur deposition on the area of the CR has not reached 50 000 t, and since 2015 has fallen below 40 000 t. The values of the wet deposition of sulphur in 2000–2007 ranged from 30 000 to 50 000 t, except lower deposition in 2003 (19 128 t). Since 2008, depositions have not exceeded 30 000 t, and after 2015 the downward trend below 20 000 t continues. The values of dry deposition were around 30 000 t until 2006, and in 2007 and 2008 there was a significant decrease to values below 20 000 t. After an increase in deposition between 2009 and 2014, steady to slightly decreasing values have been observed in the last five years, in accordance with the level of sulphur dioxide concentrations in the ground-level atmosphere.

Since 2001, the annual deposition of sulphur on the forested area of the CR (26 428 km^2) has shown a rather declining trend (Table IX.3). The total and throughfall depositions in 2020 were the lowest since 2001. In some mountain areas in the country, the long-term throughfall deposition values are higher than the values of total sulphur deposition determined as the sum of wet (vertical only) and dry deposition of SO_2. This can be attributed to the contribution to deposition from fog, low clouds and rime (horizontal deposition), which are not included in the total deposition because of their uncertainty.

Total annual nitrogen deposition has ranged from 40 000 to 50 000 t since 2000. A declining trend since 2013 can be observed, except for 2017 (Fig. IX.22). For oxidized forms of nitrogen, a significant trend has been observed since 2000 in both wet and dry deposition. Fluctuations in annual deposition values are related to air pollution concentrations of NO_X in the troposphere.

Together with the variation of deposition of sulphur and nitrogen (Hůnová et al. 2014), variation can be seen in the mutual ratio of these two elements in atmospheric precipitation, related to trends in the emissions of particular compounds (Fig. IX.20). A slight, although not steady, increase in the ratio of nitrates to sulphates has been observed at some stations since 2000 (Hůnová et al., 2017).

Since 2000, no trend of hydrogen ion deposition has been observed. The values of total deposition range between 2 500 and 4 500 t .year^{-1} (Fig. IX.23). Since 2015, the total deposition of hydrogen ions has not exceeded 3 000 t.

In the second half of the 1990s, there was a decrease in the wet deposition of some substances at selected stations in the CR (mainly SO_4^{2-}, H^+ and Pb_2^+). Since 2000, the values have rather stagnated, though after 2010 there has again been a slight decrease in some substances. These are, for example, H^+ at all stations, and NO_3^- especially at Souš and slightly also at the Svratouch, Košetice and Přimda localities (Fig. IX.24).

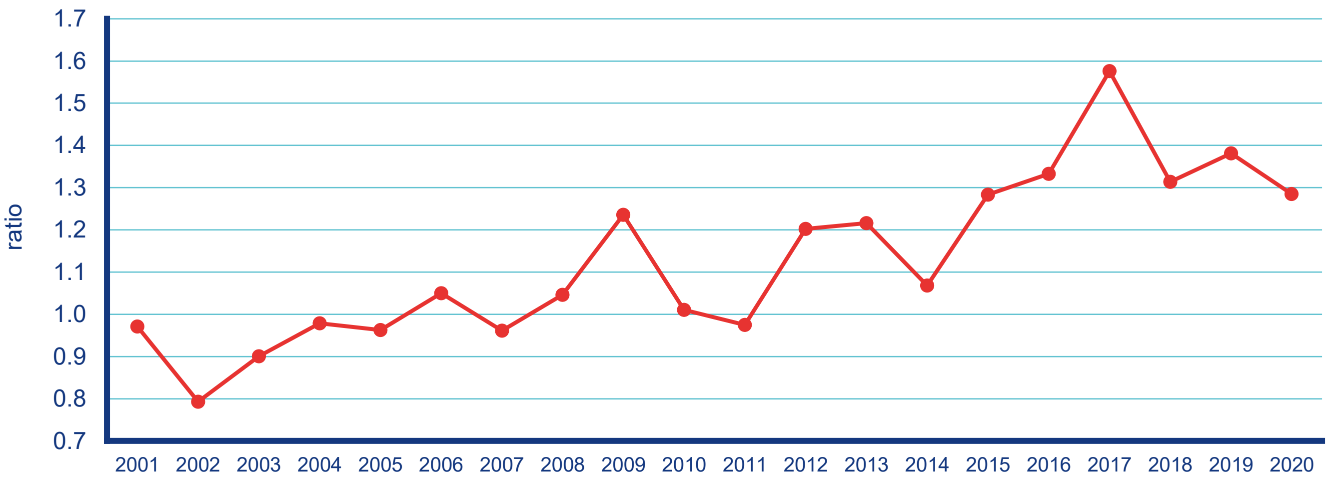

Fig. IX.20 Ratio of nitrate to sulphate concentrations in atmospheric deposition (expressed as μeq.l^{-1}) at the CHMI localities, 2000–2020

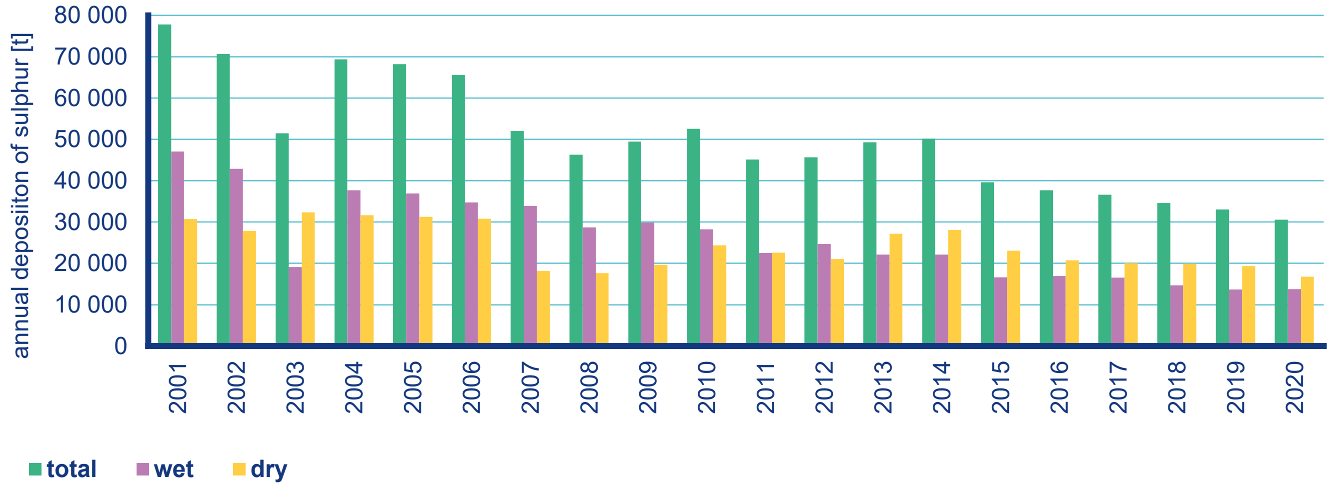

Fig. IX.21 Annual deposition of sulphur (S_SO_4^{2-}, S_SO_2) on the area of the Czech Republic, 2000–2020

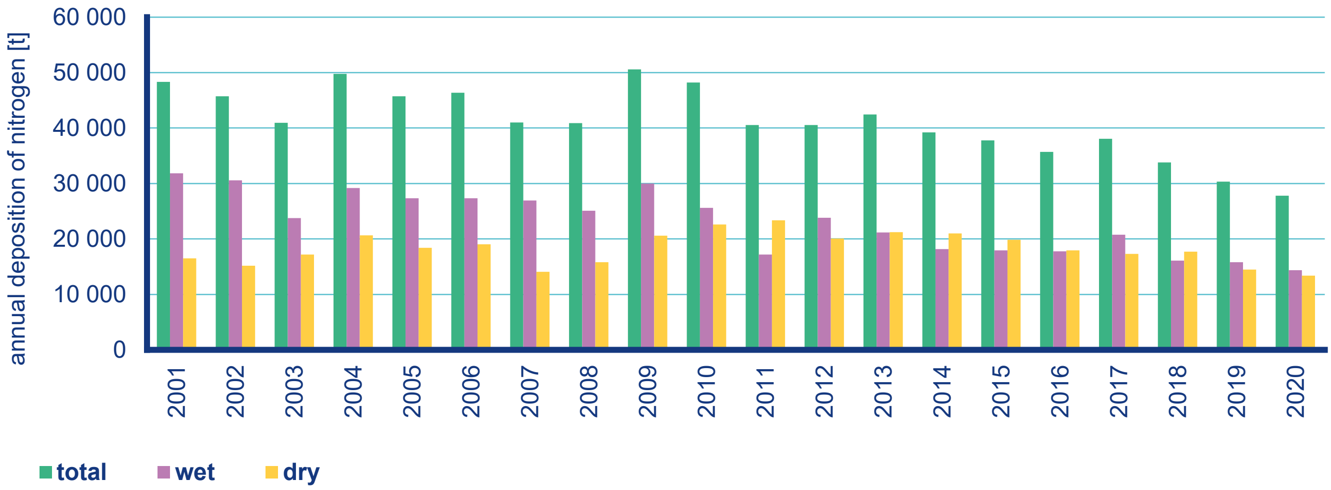

Fig. IX.22 Annual deposition of oxidized forms of nitrogen (N_NO_3^-, N_NO_x) on the area of the Czech Republic, 2000–2020

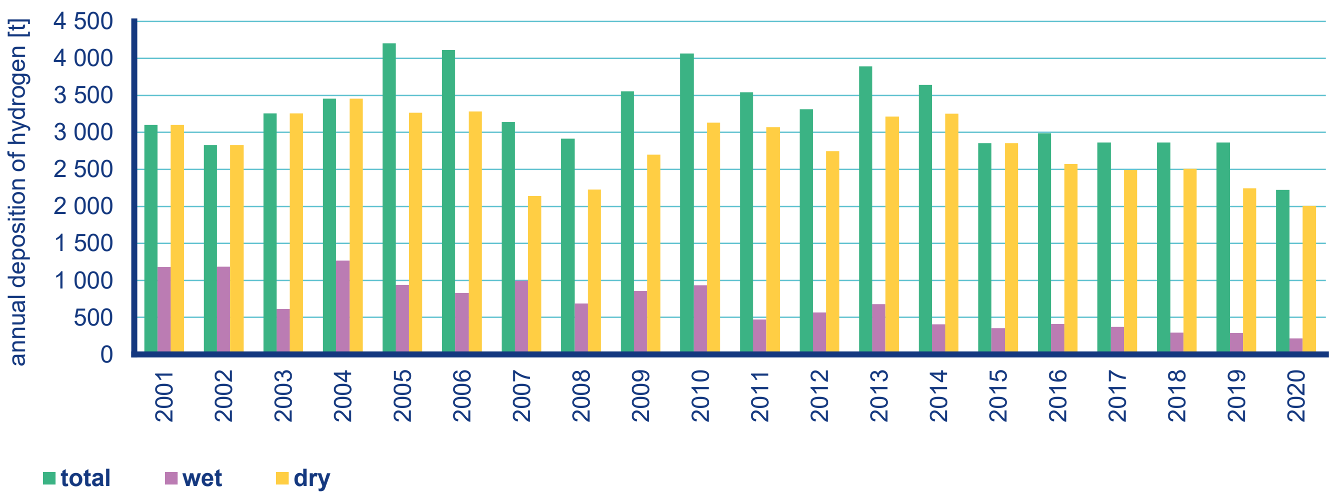

Fig. IX.23 Annual deposition of hydrogen ions on the area of the Czech Republic, 2000–2020

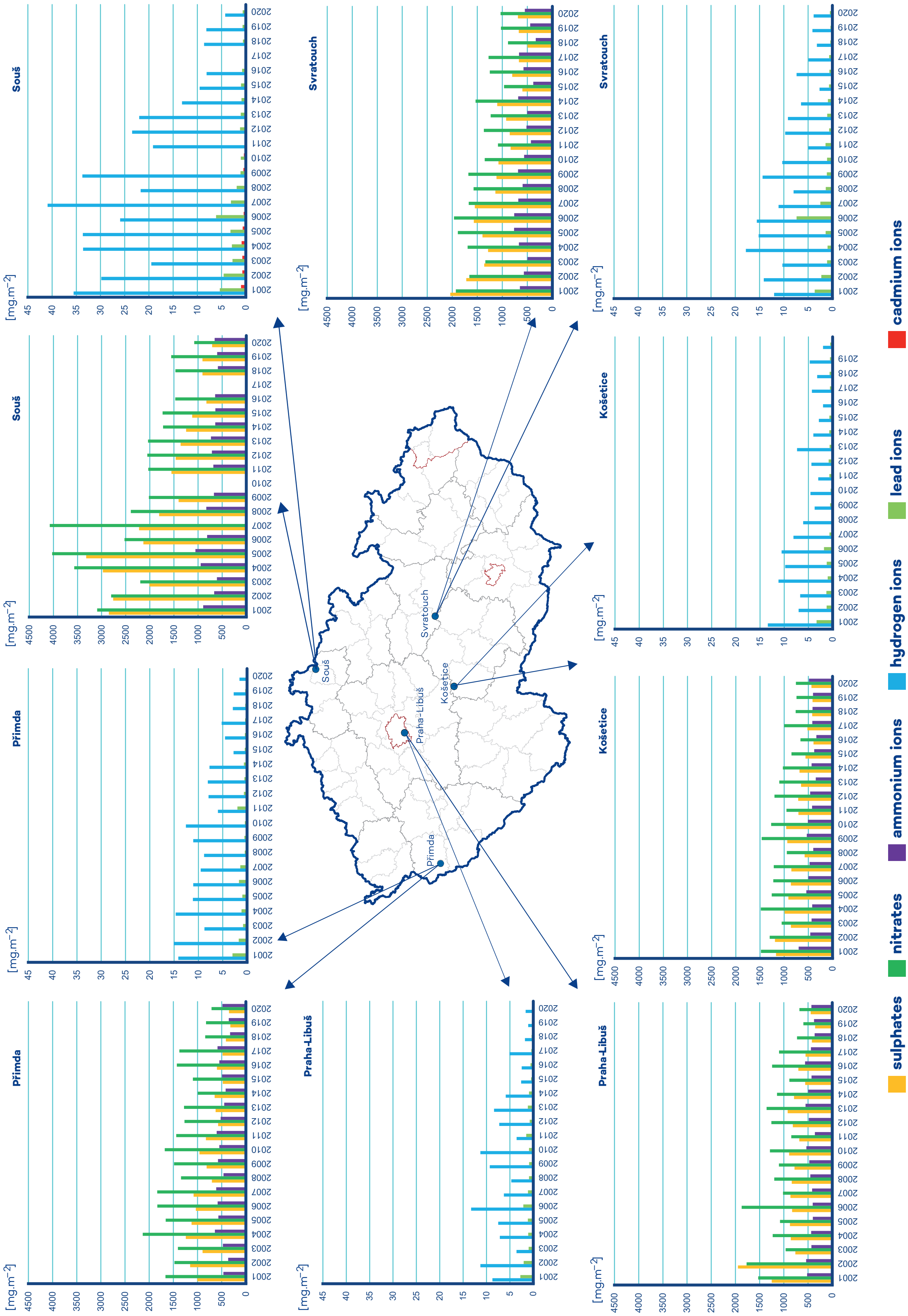

Fig. IX.24 Annual wet deposition at selected stations, 2000–2020

Table IX.4 Station networks monitoring atmospheric precipitation quality and atmospheric deposition, 2020

Code	Station	Region/country	District	Owner	Data supplier	Altitude [m]	Sampling
ALIB	Pha4-Libuš	Prague	Praha 4	CHMI	CHMI	301	W1(HM)
BKUC	Kuchařovice	South Moravian	Znojmo	CHMI	CHMI	334	W1(HM)
CCHU	Churáňov	South Bohemian	Prachatice	CHMI	CHMI	1118	W1(HM)
CKAM	Kamýk-Všeteč	South Bohemian	České Budějovice	VÚLHM	VÚLHM	593	M2(HM), M4(HM)_bu
CKOC	Kocelovice	South Bohemian	Strakonice	CHMI	CHMI	519	W1(HM)
CLIZ	Liz	South Bohemian	Prachatice	ÚH AV ČR	CGS	828	M2(HM), M4(HM)_sm, M4(HM)_bu
CPL1	Plešné jezero	South Bohemian	Prachatice	HBÚ AV ČR	HBÚ AV ČR	1087	F2
CPL2						1122	F2
CPL3						1334	F2
EPOM	Polomka	Pardubice	Chrudim	ÚVGZ AV ČR	CGS	512	M2(HM), M4(HM)_sm
ESVR	Svratouch	Pardubice	Chrudim	CHMI	CHMI	735	W1(HM)
HKRY	Krkonoše-Rýchory	Hradec Králové	Trutnov	CHMI	CHMI	1001	W1(HM)
HLUD	Luisino údolí	Hradec Králové	Rychnov nad Kněžnou	CHMI	CHMI	875	W1(HM)
HLUU	Luisino údolí	Hradec Králové	Rychnov nad Kněžnou	VÚLHM	VÚLHM	940	M4(HM)_sm
HMOP	Modrý potok	Hradec Králové	Trutnov	ČGS	CGS	1010	M2(HM), M4(HM)_sm
HUDL	U dvou louček	Hradec Králové	Rychnov nad Kněžnou	VÚLHM	CGS	880	M2(HM), M4(HM)_sm, M4(HM)_bu
IGWL	Gorzów Wlkp	Lubušský	Gorzów Wielkopolski	GIOS	GIOS	72	M1(HM)
IZGO	Zielona Góra	Lubušský	Zielona Góra	GIOS	GIOS	192	M1(HM)
JKOS	Košetice	Vysočina	Pelhřimov	CHMI	CHMI CGS	535	D1(HM) (POPs,PAHs), M2(HM), M4(HM)_sm
JLKV	Loukov	Vysočina	Havlíčkův Brod	CGS	CGS	500	M2(HM), M4(HM)_sm
JSAL	Salačova Lhota	Vysočina	Pelhřimov	CGS	CGS	557	M2(HM), M4(HM)_sm
JZEL	Želivka	Vysočina	Havlíčkův Brod	VÚLHM	VÚLHM	440	M2(HM), M4(HM)_sm
KLAZ	Lazy	Karlovy Vary	Cheb	VÚLHM	VÚLHM	875	M2(HM), M4(HM)_sm
KLY1	Lysina	Karlovy Vary	Cheb	CGS	CGS	867	M2(HM)
KLY2						836	M4(HM)_sm
KNZ1	Na Zeleném	Karlovy Vary	Cheb	CGS	CGS	773	M2(HM)
KNZ2						750	M4(HM)_sm
KPB1	Pluhův bor	Karlovy Vary	Sokolov	CGS	CGS	753	M2(HM)
KPB2						714	M4(HM)_sm
LSOU	Souš	Liberec	Jablonec nad Nisou	CHMI	CHMI	771	W1(HM)

Code	Station	Region/country	District	Owner	Data supplier	Altitude [m]	Sampling
LUHL	Uhlířská	Liberec	Jablonec nad Nisou	CGS	CGS	780	M2(HM), M4(HM)_sm
PBEN	Benešovice	Plzeň	Tachov	VÚLHM	VÚLHM	535	M2(HM), M4_bo
PCJ1	Čertovo jezero	Plzeň	Klatovy	HBÚ AV ČR	HBÚ AV ČR	1180	F2
PCJ2						1057	F4_sm
PPRM	Přimda	Plzeň	Tachov	CHMI	CHMI	740	W1(HM)
SLES	Lesní potok	Central Bohemian	Kolín	GLÚ AV ČR	CGS	400	M2(HM), M4(HM)_sm, M4(HM)_bu
SLI1	Litavka1	Central Bohemian	Příbram	CGS	CGS	700	M2(HM)
SLI2						710	M4(HM)_sm
TBKR	Bílý Kříž	Moravian-Silesian	Frýdek-Místek	CHMI	CHMI	890	W1(HM)
TCER	Červená hora	Moravian-Silesian	Opava	CHMI	CHMI	749	W1(HM)
TCRV	Červík	Moravian-Silesian	Frýdek-Místek	VÚLHM	CGS	640	M2(HM), M4(HM)_sm
TKLE	Klepačka	Moravian-Silesian	Frýdek-Místek	VÚLHM	VÚLHM	650	M2(HM), M4(HM)_sm
UJEZ	Jezeří	Ústí nad Labem	Chomutov	CGS	CGS	820	M2(HM), M4(HM)_sm, M4(HM)_bu, M4(HM)_br
UMOD	Moldava	Ústí nad Labem	Teplice	VÚLHM	VÚLHM	805	M2(HM), M4(HM)_je
URVH	Rudolice v Horách	Ústí nad Labem	Most	CHMI	CHMI	840	W1(HM)
VLEG	Legnica	Dolnoslezský	Legnica	GIOS	GIOS	122	M1(HM)
VSNI	Sniezka	Dolnoslezský	Jeleniogorski	GIOS	GIOS	1603	M1(HM)
WKAT	Katowice	Slezský	Katowice	GIOS	GIOS	284	M1(HM)
WRAC	Racibórz	Slezský	Racibórz	GIOS	GIOS	205	M1(HM)
ZBUC	Buchlovice-Medlovice	Zlín	Uherské Hradiště	VÚLHM	VÚLHM	350	M2(HM), M4(HM)_du
ZMAR	Maruška	Zlín	Vsetín	CHMI	CHMI	664	W1(HM)

Explanatory notes:

D1 – daily wet-only - autom. sampler
F2 – bulk- irregular samples
F4 – throughfall- irregular samples
M1 – monthly wet-only - autom. sampler
M2 – monthly bulk samples
M4 – monthly throughfall
W1 – tweekly wet-only - autom. sampler

_bo – pine
_br – birch
_bu – beech
_du – oak
_je – rowan
_sm – spruce

(HM) – heavy metals analysis in mentioned sampling
(POPs, PAHs) - POPs and PAHs analysis